THE LATE S. G. S. PANISSET.

IT is with feelings of sadness and deep regret that we record the death of Mr. S. G. S. Panisset, Director of Research of the Associated Portland Cement Manufacturers, Ltd., and Consulting Technical Editor of CEMENT AND CEMENT MANUFACTURE since its inception. Following a heart attack five weeks previously, Mr. Panisset passed away peacefully at his home at Sutton, Surrey, on March 22, at the age of 59 years.

Shortly after leaving the City and Guilds Technical College in 1896, Sidney Glyde Stephen Panisset took up an appointment as chemist at the cement works of Martin Earle & Co.,

THE LATE S. G. S. PANISSET.

near Rochester. In 1907 he was appointed chief chemist of the Saxon Portland Cement Co., Ltd., and the Norman Portland Cement Co., Ltd., and when these businesses were taken over in 1912 by the British Portland Cement Manufacturers, Ltd., he became Works Supervisor of the Associated Portland Cement Manufacturers, Ltd. In 1931 he was appointed Director of Research of the Associated Portland Cement Manufacturers, Ltd., and held this position until his untimely decease.

Mr. Panisset's great ability, his kindly nature, his ready smile of welcome, made for him a host of

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friends in the cement and civil engineering industries. While the improvement in the quality of Portland cement was his first concern, he always had in mind the requirements of the user. His working life was a strenuous one, but he always found time to help those who sought his advice. He had the same welcome, and the same ready understanding of the problem, whether the benefit of his experience were sought by a small maker of concrete products, by an engineer engaged on large civil engineering works, or by other research workers. In all he did he was thorough.

He wrote but little. He felt he could better serve the industry by encouraging others to add to the literature of the subject, and to them he gave unstinted help. Mr. Panisset was a man who shrank from publicity. He had more satisfaction in carrying out and directing research work on behalf of the great undertaking to which his life was devoted and in helping cement users in their problems. He rarely took part in the discussions of learned societies, but when he did so his views were listened to with the respect due to one who, with great experience and a deep sense of responsibility, spoke only of what he knew and knew of what he spoke. A good linguist, his many journeys abroad enabled him to keep abreast of new developments in the manufacture and uses of cement in all parts of the world.

Although his name was not so well known to engineers and chemists generally as that of others engaged in cement research, his great knowledge and experience were known and appreciated throughout the world by those best qualified to judge his ability.

During the past few years he had devoted a great deal of attention to the production of special cements for special purposes, and had been elected to the Committee of the Institution of Civil Engineers which is considering this subject. His advice was sought by many other professional and trade associations. He took an active part in the preparation of the British Standard Specification for Portland Cement and of the specifications for certain pre-cast concrete products, and at the time of his death he was concerned with the difficult problem of producing a standard specification for lime.

The cement industry has lost a keen and far-seeing research worker. Cement users will miss the help of an able adviser. This journal has lost an inspiring counsellor. All mourn a friend, taken in the prime of his achievement.

From Mr. A. C. DAVIS.

Mr. A. C. Davis, M.I.Mech.E., M.Inst.C.E.I., F.C.S., Works Managing Director of the Associated Portland Cement Manufacturers, Ltd., writes :

" For the long period of more than thirty years the cement industry of Great Britain never had a more able, more resourceful, or a more uniformly efficient yet prudent representative. By mutual understanding with his colleagues the problems and anxieties inseparable from a complicated and highly technical business life were materially lightened. Mr. Panisset was a man of great ability, thorough training, and wide outlook. His keen initiative, sound judgment, and hard work, combined with his great qualities of serenity, sympathy, and sagacity, made him an ideal colleague for his fellow workers, who will greatly miss his counsel and his companionship."

Special Cements for Mass Concrete Structures.

By F. M. LEA, D.Sc., F.I.C.

(OF THE BUILDING RESEARCH STATION)

THE following report on special cements for mass concrete structures* is reprinted by permission from the *Journal of the Institution of Civil Engineers* (February, 1937).

The term " special cements " is used to cover cements in which some modification of the properties of Portland cement is introduced to provide the user with a material more suited to certain requirements than the normal or rapid-hardening products of the present day. Special cements may be Portland cements falling within the composition limits of the British Standard Specification for Portland Cement, but in some cases they fall into a class which is often termed " blended cements." Such cements are composed of a mixture of Portland cement and another material ; for example, pozzolanic cements contain a mixture of Portland cement and a pozzolanic material. Portland blastfurnace cement also belongs to the class of blended cements since it is composed of a mixture of Portland cement and granulated blastfurnace slag.

The most widespread demand for special cements has come from engineers engaged in the construction of large mass concrete works. At the First International Congress on Large Dams held at Stockholm in 1933 attention was directed to the need for cements of special properties for use in concrete dams. Stress was laid in particular on the desirability of reducing shrinkage cracking. It was recognised that a major factor involved in shrinkage cracking was the high temperatures attained in such large concrete masses, owing to the heat evolved during the hydration of cement and to the thermal contraction which occurs on subsequent cooling. The desirability of obtaining cements with a lower heat evolution was thus brought to the fore.

In the present report it is proposed to review the progress which has been made in the production of low-heat cements and to discuss the specification and properties of such cements. Particular attention will be paid to the forms of specification now used in the U.S.A. since they involve a radical departure from usual methods.

After the meeting in Stockholm of the International Congress on Large Dams, an International Sub-Committee on Special Cements was set up under its ægis and corresponding national committees were established in many countries. In Great Britain a Sub-Committee on Special Cements was set up in 1934 by the British National Committee on Large Dams, and later this committee was reconstituted as a joint committee of the Institution of Civil Engineers and the British Committee on Large Dams.

During recent years considerable experience has been gained in the U.S.A in the use of special cements for dams. Notable examples are to be found in

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Boulder dam on the Colorado river and Grand Coulee dam on the Columbia river together with many smaller structures coming under the authority of the U.S. Bureau of Reclamation ; Norris dam in the Tennessee basin under the Tennessee Valley Authority ; Bonneville dam on the Columbia river and Tygart river dam in the upper Ohio river basin under the U.S. Army Engineers ; and Morris dam built by the Water Department of Pasadena. Of these dams, Boulder, Morris, and Norris are completed, whilst construction is in progress on all the others.

The general reporter on " Special Cements " to the Washington Congress was Mr. J. L. Savage, Chief Designing Engineer to the U.S. Bureau of Reclamation. An addendum to his report dealt specifically with the Interim Report of the International Sub-Committee on Special Cements. General agreement was expressed with the conclusions of the International Sub-Committee as to methods of testing heat of hydration and solubility of cements and on the general principles enunciated for the testing of permeability. The reporter then went on to say : " As a complement to the plan for developing standard test methods for the five selected properties (heat-evolution, solubility, permeability, shrinkage, and workability) it is assumed that the sub-committee contemplates that cements tested by such methods will likewise be tested for revealing their chemical and physical properties. This is considered a matter of the greatest importance, particularly with regard to cement fineness and chemical composition which play so prominent a role in the physical behaviour of concrete and consequently in the interpretation of the various test data. So dominant, in fact, is the influence of fineness on some of the properties of cement in concrete, at least within a certain range of specific surface, that provision for its reliable determination might easily be considered of greater concern in the study of special cements than any of the test methods dealt with in the sub-committee's interim report." The inference in this statement, that once the chemical composition and fineness of cements (of the Portland cement type) are specified the properties of the cements directly follow, forms the basis of the more recent U.S. specifications for special cements.

The work and attitude of the International Sub-Committee brings into marked contrast the different ideas of cement specification methods at present held by the European and the American authorities. The European approach to the problem, as evidenced by the interim report of the International Sub-Committee, has been to endeavour to formulate tests for the properties desired and to leave it to the manufacturer to produce as best suits him a cement conforming to those tests. In the American form of specification as now used for special cements, a form which is also extending into other fields such as cements for concrete roads, the composition and fineness of the cement are prescribed to the manufacturer, and the engineer formulating the specification assumes the responsibility that the material will have the physical properties desired. This method of specification, first introduced by the U.S. Bureau of Reclamation, has as its basis a very large amount of fundamental research work on cements and of experience in construction. A very valuable summary of this research work

and of practical experience in construction was presented by Mr. J. L. Savage to the Washington Congress under the title " Special Cements for Mass Concrete." Before proceeding to discuss the recent American specifications in detail it should be mentioned that not all authoritative opinion in the U.S.A. is in agreement with the theoretical basis of these specifications, whilst it is also held by some that they may prove unduly restrictive of future developments.

A brief digression into the chemistry of Portland cement is necessary here for the full appreciation of the U.S. specifications. Portland cement is mainly composed of lime, silica, alumina, iron oxide, and magnesia. Modern research has established that the compounds formed from these oxides in the burning of cement clinker are tricalcium silicate ($3CaO.SiO_2$), dicalcium silicate ($2CaO.SiO_2$), tricalcium aluminate ($3CaO.Al_2O_3$), tetracalcium aluminoferrite ($4CaO.Al_2O_3.Fe_2O_3$) and uncombined magnesia. From the ordinary oxide analysis of a cement, together with a determination of the amount of lime remaining uncombined, an arithmetical calculation can be made and the composition of the cement expressed in terms of these various compounds. The compound composition is only another method, though for many purposes a very convenient method, of representing the cement analysis, and the accuracy of the calculated contents of the various compounds is dependent on certain assumptions which do not appear in the arithmetical procedure. It is known that other compounds beyond those mentioned may be present to some extent and that the calculation as described is not entirely correct, but the extent of the errors is at present uncertain. Modern research has also shown that tricalcium silicate is mainly responsible for the early strength of cements and dicalcium silicate for the strength developed from 14 or 28 days onwards ; the iron-containing compound contributes little strength at any age, and the tricalcium aluminate, though contributing somewhat to early strength, causes a reduced strength at long ages. Tricalcium aluminate has the greatest heat of hydration, tricalcium silicate next, and dicalcium silicate and the iron compound least. It will be evident that, as the compounds mainly responsible for the early strength development in Portland cement have also a high heat evolution on hydration, some sacrifice of strength at early ages (although not at long ages) must be made if a low heat evolution is desired. The effect of these different compounds on shrinkage and durability is more uncertain, apart from the special case of resistance to attack by sulphate-bearing waters in which the tricalcium aluminate is the most vulnerable. The basis of the U.S. specifications is a limitation of the compound content of cements in such a way as, when combined with a certain specified minimum fineness, to obtain the particular properties desired. The test of fineness is not a sieve test, but a much more refined measurement of the surface area per unit weight of the cement, for which suitable methods have been developed. A strength test is at present retained, but the specified strength is low.

That form of specification has clearly many attractions for it depends mainly on chemical tests and fineness tests which are both accurate and rapid, though probably most European authorities are in agreement with some dissenting

American opinion that it represents a step which is not yet sufficiently supported by knowledge.

The low-heat cement used for Morris dam in California (originally called Pine Canyon dam) was the first to be supplied under a specification which placed a limit on the heat evolution. This dam was built during 1932–34 ; at the time the specification was drafted the cement investigations carried out for Boulder dam were in progress and information on the properties of the low-heat cements was available. The Morris dam cement specification was based mainly on physical properties and the only chemical limitation, apart from the limits for magnesia, sulphur trioxide, and loss on ignition which are found in all cement specifications, was one on the content of tricalcium aluminate. The first specification for low-heat cement for Boulder dam was issued in 1933 and revised specifications followed later, the last specification being issued in 1934. Some difficulty was experienced by cement manufacturers in supplying cement to conform with the heat-evolution requirements of the original 1933 specification, and in the 1934 specification the maximum permissible heat evolution was raised. In the Boulder dam specifications for low-heat cements limitations were placed on the contents of tricalcium silicate, dicalcium silicate, tetracalcium alumino-ferrite, and the ratio of ferric oxide to alumina. Details of these specifications are given in Table I.

The original Morris dam specification permitted a maximum residue of 15 per cent. on a 200-mesh sieve, but when construction started it was found with the cement from one manufacturer that excessive separation of water from the concrete occurred in placing. The fineness limit was therefore altered to a maximum of 8 per cent. residue on the 200-mesh sieve[1] and thereafter no trouble was found.

The concrete in Morris dam was placed with the aid of internal vibrators. This was also the case for all the later dams, with the exception of Boulder dam of which only parts were vibrated. American authorities attach much importance to high fineness in cements, as it has been found that the separation of water from concrete during vibration is thereby reduced. In the specifications for cements for the dams constructed subsequent to Morris dam, the fineness is controlled by a requirement of a minimum surface area per gram of cement. The actual figures inserted in the specifications for surface area cannot be directly compared with the sieve-residue values used in this country, but from measurements made at the Building Research Station of the surface area of British cements it appears that the fineness of the cements used in the American dams is comparable with that of the rapid-hardening Portland cements marketed here. It should be noted that sieve tests are of very little value for controlling the fineness of cements, and that, when considerable importance is attached to this

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[1] The U.S. 200-mesh sieve has an opening of 0.0074 centimetre compared with one of 0.0089 centimétre in the B.S. 170-mesh. For a given fineness the residues are therefore higher on the U.S. 200 sieve than on the B.S. 170 sieve.

TABLE I.—UNITED STATES SPECIFICATIONS FOR LOW-HEAT AND MODIFIED PORTLAND CEMENTS.*

		Low-heat Portland cements			Modified Portland cements		
		Morris dam 1932–34	Boulder dam		Norris dam 1934	Grand Coulee dam 1935	Tygart river dam 1935
			June 1933	March 1934			
Chemical composition.							
Tricalcium sili-cate : per cent.	Not less than ..	—	—	—	35	35	35
	Not greater than	—	40	40	55	55	50
Dicalcium sili-cate : per cent.	Not greater than	—	60	65	—	—	—
Tricalcium alumi-nate : per cent.	Not greater than	6	6	7	8	7	8
	Not less than ..	1	—	—	—	—	—
Tetracalcium alu-minoferrite : per cent.	Not greater than	—	20	20	—	—	—
Ratio of Fe_2O_3 to Al_2O_3.	Not greater than	—	1.5	1.5	1.5	—	—
Uncombined lime (CaO) : per cent...		—	—	—	—	1.25	—
Fineness.							
Residue on 200-mesh sieve : per cent.	Not greater than	8	—	—	—	—	—
	Not less than ..	2	—	—	—	—	—
Specific surface : square centi-metre per gram.	Not less than ..	—	1,800	1,700	1,600 (later 1,800)	1,800	1,600
	Not greater than	—	2,300	2,300	2,200	—	2,200
Heat of hydration (calories per gram) :							
7 days. Not greater than		65	60	65	—	—	—
28 days. ,, ,, ...		80	70	75	—	—	—
Compressive strength (lb. per square inch) :							
1 : 3 standard sand mortar cylinders 2 in. by 4 in. Water about 10 per cent. by weight of dry materials.							
7 days		800	1,000	1,000	—	—	—
28 days		2,000	2,400	2,000	—	—	—
Minimum per cent. increase :							
7 to 28 days		35	35	35	—	—	—
1 : 2.77 graded sand plastic mortar 2-in. cubes. Water about 14 per cent. by weight of dry materials.							
3 days		—	—	—	750	—	750
7 days		—	—	—	1,500	1,500	1,500
28 days		—	—	—	2,500†	2,500	2,500
Minimum per cent. increase :							
7 to 28 days		—	—	—	28-day strength greater than 7-day	25	—

* These specifications also include setting-time, soundness tests and limits for magnesia sulphur trioxide and ignition loss.   † Not required as acceptance test.

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property, the use of more refined methods of measurement, such as the American methods for surface area, becomes essential.

At Morris dam, where the climate was hot in summer and mild in winter, the rate of hardening of the low-heat cement was satisfactory and the shuttering could be removed within the intended time, about three days   It was originally intended to use the low-heat cement throughout at Boulder dam, but the rate of hardening of this cement in winter was found to be rather too slow for the rapid rates of construction employed ; a blend of 60 per cent. low-heat and 40 per cent. normal Portland cements was therefore used during cold weather.   It is stated, however, that rather slight changes in construction procedure would have eliminated the necessity for this expediency.

In the dams on which construction has been started subsequent to Boulder dam, such as Norris dam in the Tennessee valley, Grand Coulee dam on the Columbia river, and Tygart river dam in the upper Ohio river basin, a type of cement known as " modified " or " moderate heat " Portland cement has been used.   This cement, which has been adopted as a compromise, evolves on an average about 10 per cent. less heat than normal Portland cement, as compared with a figure of about 27 per cent. less for low-heat cement, but it has a rate of strength development about the same as that of normal Portland cement.   It differs mainly from normal Portland cement in having a low content of tricalcium aluminate.   There are certain differences in the specifications, as shown in Table I, for the modified cement for the three dams mentioned and attention may be directed to that for Grand Coulee dam as it represents the most highly developed form of the new American type of specification.   Maximum and minimum limits are placed on the tricalcium silicate content and a maximum limit on the content of tricalcium aluminate.   A maximum limit is also set to the content of uncombined lime.   This limitation will rule out a cement which has a high lime-content, but is underburnt and, owing to combination of the lime not being complete, still contains a tricalcium silicate content below the maximum specified.   No direct test is required for heat evolution as it is considered that the composition requirements are adequate to control this.   A high fineness, similar to that of rapid-hardening Portland cements in this country, is again required.   The specified strength is at a low level though somewhat above that in the Boulder dam low-heat cement.   The strength test in both the Boulder and Grand Coulee cement specifications is a compressive test on a mortar, but the form and composition of the test piece differ.   After allowing for the difference introduced in this way the minimum strength required in the Coulee cement is about one-third higher at 7 days than that in the Boulder cement, and slightly higher at 28 days.   The strength test appears only to be retained in the Grand Coulee cement specification as a precautionary measure and reliance is placed primarily on the composition and fineness requirements to ensure a cement of the required properties.

. The average heat evolution of American cements of various types is given by Mr. J. L. Savage as follows :

TABLE II.

Cement	Heat of hydration (calories per gram)		
	3 days	7 days	28 days
Rapid-hardening Portland	102	108	114
Normal Portland	79	86	91
Modified Portland	63	74	82
Low-heat Portland	44	52	65
Boulder dam low-heat cement-specification ..	—	65	75

These values are all based on the American "heat of solution" method. Relatively few directly comparable values on British cements are available as practically all tests in this country have been made by the adiabatic calorimetric method. Values on three British normal Portland cements by the American "heat of solution" method have, however, given values of 72 to 96 calories per gram at 7 days and 94 to 114 at 28 days.

As mentioned before, the strength requirements in the American low-heat and modified cement specifications are low and the actual strength of the cements supplied has been considerably above the limits specified. The average values for the low-heat cements from five different manufacturers supplied for Boulder dam are shown in Table III.

TABLE III.—MORTAR TESTS ON LOW-HEAT CEMENTS SUPPLIED FOR BOULDER DAM.

Cement	Compressive strength : lb. per sq. in. (1 : 3 standard sand mortar with 10 per cent. water) 4-in. by 2-in. cylinder	
	7 days	28 days
A	1,750	3,420
B	1,660	3,630
C	1,530	3,300
D	2,320	4,570
E	1,680	5,300
Specification requirement	1,000	2,000

The results on the modified cements supplied for Grand Coulee dam given in Table IV also show actual strengths much above the specification requirement.

TABLE IV.—MORTAR TESTS ON MODIFIED CEMENTS SUPPLIED FOR GRAND COULEE DAM.

Cement	Compressive strength : lb. per sq. in. (1 : 2.77 graded sand mortar with about 14 per cent. water) 2-in. cubes	
	7 days	28 days
1	2,137	4,401
2	2,940	5,250
3	3,435	5,060
4	3,200	5,330
5	3,160	6,200
Specification requirement	1,500	2,500

From various results it appears that the compressive strength of concrete made from the Boulder dam low-heat cements is rather below one-half of that obtained with normal Portland cement at 7 days and about three-quarters of that at 28 days. The modified cements give a slightly lower concrete strength than average normal Portland cement at 7 days and an equal strength at 28 days. Both the low-heat and modified cements show rather higher strengths at long ages (six months and upwards) than normal Portland cement.

Particular interest attaches to the cement being used for the construction of Bonneville dam on the Columbia river in the U.S.A. This cement is a pozzolanic cement composed of 75 per cent. cement clinker of the modified Portland cement type and 25 per cent. of a pozzolana prepared by burning, at about 1,650 deg. F., a dredged mud. The clinker and pozzolana are ground together to a fineness which is even greater than that required for the low-heat and modified Portland cements discussed earlier. The heat evolution of this cement is intermediate between that of low-heat and modified Portland cement. Though no advantage is gained in compressive strength, the tensile strength of concrete made with this pozzolanic cement has been found somewhat superior to that of modified Portland cement concrete. It is also stated that the concrete shows improved workability and less tendency to water separation when placed by internal vibration methods. Pozzolanic cements in general have a higher temperature coefficient of strength development than Portland cements and are apt to become very slow in hardening at low temperatures. It has been found, however, at Bonneville dam that in cold weather (35 to 40 deg. F.) the shuttering can still be stripped after three days provided that this is done carefully to avoid damage to the concrete. An addition of 10 per cent. more cement to the concrete is made in cold weather as a safeguard. The specification for this cement requires separate tests on the pozzolana and the Portland cement clinker and also tests on the finished blended cement.

Although low-heat cements have now been manufactured in a number of countries in addition to the U.S.A., the only other country in which appreciable practical experience is available is Sweden. The development of low-heat cement in Sweden was contemporary with that in the U.S.A. Three forms of low-heat cement have been made, a low-heat Portland cement first marketed in 1932 and two low-heat pozzolanic cements first produced commercially in 1934. The two pozzolanic cements were made by grinding a pozzolana with normal and low-heat Portland cement respectively, and they have different rates of heat evolution and hardening. Details of these cements and experience in their use were included in reports from Sweden to the Washington Congress. The heat evolution of these cements as determined by the American heat of solution method is shown in Table V.

The low-heat Portland cement is intermediate between the American low-heat and modified Portland cements in its heat evolution up to seven days and similar to the American modified cement in the 28-day value. The strength properties also appear to follow a similar course. The Swedish low-heat Portland cement

TABLE V.—COMPARATIVE HEAT-EVOLUTION OF SWEDISH CEMENTS.

Cement	Heat evolution (calories per gram)		
	3 days	7 days	28 days
Normal Portland	80	94	104
Low-heat Portland	57	69	86
Pozzolanic containing normal Portland cement	61	75	85
Pozzolanic containing low-heat Portland cement	57	66	72

differs, however, from the American cements in that it is more coarsely, instead of more finely, ground than the average normal Portland cement. This is done in order to obtain a rather prolonged time of initial set, thus assisting in the placing of large masses of concrete. It involves, however, the disadvantage that the workability of the concrete is reduced and in practice it has been found desirable to add a small amount of diatomaceous earth (3 per cent. by weight of the cement) to the concrete mix to offset this. The different views held in the U.S.A. and Sweden in regard to the fineness desirable probably arise, in part at least, from differences in the methods of construction and the extent to which large-scale mechanical aids are used to facilitate rapid placing of the concrete.

The Swedish pozzolanic cements are ground more finely than the low-heat Portland cement. Details of practical experience are only available for the cement blended with a normal Portland cement. This is stated to yield concrete with a workability similar to that obtained from the normal Portland cement. The strength characteristics are similar to those of the low-heat Portland cement, the 7-day compressive strength being about 70 per cent. of that of normal Portland cement and the 28-day strength equal or higher. The method of specification adopted in Sweden is to specify the heat evolution and strength required and not to use detailed requirements as to the chemical composition and compound content of the cement as in the American specifications.

No low-heat cement has been produced in Great Britain on a commercial scale up to the present, but manufacturers are now actively interested in the production of such special cements. The Joint Sub-Committee on Special Cements of the Institution of Civil Engineers and the British National Committee on Large Dams is at the same time endeavouring, with the aid of the information now at its disposal, to formulate the tests to which such cements should be required to conform.

The Agricultural Outlet for Lime.

By H. V. GARNER,

OF THE ROTHAMSTED EXPERIMENTAL STATION.

BEFORE the days of artificial fertilisers, lime and dung formed the basis of soil fertility. The scheme was simple, and met the demands of a system that was substantial, though not intensive in the modern sense of the word. Clauses relating to the use of stipulated quantities of lime in each rotation appeared in farm leases, so that in those days liming was an established and general practice. The old system stood by its results. Dung provided the nitrogen, phosphoric acid, and potash required for crop growth, while the lime maintained a healthy condition in the soil. Both manures were markedly effective in improving the working qualities of the land, a part that is of first-rate importance.

There is little doubt that in those days liming was sometimes overdone. Lime and labour were cheap, dressings were very heavy, and there was no scientific method of deciding the need for lime in particular cases. Gradually the position changed. In the middle of the nineteenth century the newer artificial fertilisers came into use, and farmers spent money in this direction that had formerly been laid out on lime. For a period farmers were able to live on the capital stored up in their farms as a legacy from the old system. But the users of dung-plus-artificials found that some of the artificials, far from taking the place of lime, actually made liming more necessary than before. Meanwhile, scientific study was being devoted to the chemistry and physics of the liming process, particularly in regard to the accurate diagnosis of lime deficiency and the measurement of lime requirements. The result has been to re-establish the importance of liming, not perhaps on the same wide and rather uncritical basis, but with special reference to different soils and agricultural and economic conditions.

So far as the need for lime is concerned, wide stretches in this country are well supplied with calcium compounds by nature. The thin soils on the Chalk Downs, the oolitic limestones of the Cotswolds, the chalky boulder clays of East, Anglia, and the black soils of the Fen district are important areas of this kind. Furthermore, soils deficient in lime, but closely associated with chalk or underlaid by it, are frequently dealt with by applications of the crude local material rather than by the use of commercial products. A further development of this kind has taken place in the neighbourhood of beet sugar factories, where the need for lime, often very pronounced, is largely met by the use of the waste carbonate or sugar beet lime sludge, accumulated at the works. Other areas are confined to special crops tolerant of soil acidity. The typical course of cropping, potatoes, oats and temporary grass, is well suited to districts with acid soils and fairly high rainfall and is the backbone of arable farming in many parts of the North and West. Turnips are also suitable crops in such districts, but there is some danger of finger-and-toe disease if they are grown too frequently. A further

large area of permanent grass is managed successfully without lime even where lime would be necessary for arable cultivation. There remain those soils that are naturally poor in calcium carbonate and are required for mixed husbandry, including such sensitive crops as sugar beet, barley and clovers. The more intensive the cropping both on arable and on grassland the more the need for artificial liming. This is the field for the use of prepared limes and limestone products, and we may now consider the requirements of these areas.

The first is a satisfactory method of diagnosing lime deficiency and measuring the amount of lime necessary for the purpose in view. This can now be done with sufficient accuracy for practical purposes. There is no need to wait till land is overrun with " indicator " weeds, or needlessly to apply lime to land that requires something quite different. An advisory service covers all agricultural districts, and laboratory tests coupled with knowledge of the behaviour of local soils under liming provides reliable information. It is not too much to say that more success has attended laboratory efforts to diagnose lime requirements than the requirements of the common nutrients, nitrogen, phosphate, and potash.

When using commercial forms of lime the dressings are commonly about 1 ton, and rarely exceed 3 tons per acre. This quantity only amounts to a matter of $2\frac{1}{2}$ oz. per square foot for the heaviest dressing, so that to allow even distribution the first essential is fineness of division. For lighter dressings, up to about 2 tons per acre, ground quicklime or ground limestone is used for this reason, and applied by means of a manure drill. If more than this is needed a common procedure is to purchase lump lime and slake it on the farm ; the job is rather troublesome, and its only object is to obtain the material in a powdery form suitable for distribution by shovel from small heaps spaced out over the land. Nevertheless, it is sometimes thought to be justified owing to the difference in price between lump and ground lime.

Quickness of action is closely linked up with fineness of division, and this is specially important with the harder limestones whose gritty particles weather very slowly in the soil. The question of the optimum fineness of grinding of limestone has received much study in the United States. Rather coarse material, all passing the 20-mesh sieve, is favoured for bulk transport over short distances, while for transport in bags over longer distances a fineness of 60 to 70 per cent. through the 100-mesh sieve is preferred. In England the tendency is towards finer grinding, and a material which all passes the 60-mesh sieve and a large proportion of which passes the 100-mesh sieve is usual. Very fine grinding, although sometimes practised, makes the product so costly that quicklime may be cheaper. Provided there is a preponderance of small particles the presence of a small proportion of coarser material is no disadvantage, because it facilitates distribution, since very fine flowery powder tends to cling in the drill. The dust associated with spreading quicklime is unpleasant, and for this reason users prefer some form of ground carbonate if prices are favourable.

The next point is quality. Formerly the tests that farmers could apply were of the crudest description. They knew that quicklime should slake in a

lively manner, and that the presence of ashes or unburnt cores of limestone was not desirable. A reasonable degree of fineness in ground products was looked for, but that was all. That has been changed under the provision of the Fertiliser and Feeding-Stuffs Act (1926). The Act provides that quicklime should be declared in respect of its content of CaO, slaked lime in terms of $Ca(OH)_2$, and carbonate in terms of $CaCO_3$. The two last must also be stated in terms of equivalent CaO, and the degree of fineness in terms of a standard sieve is required for ground limestone. The consignment may contain more than the stated percentage, but if it contains less compensation can be claimed by the purchaser. These provisions are useful, for by working out cash quotations in terms of the analysis, prices can be compared on a basis of unit weight of CaO. This procedure has long been familiar to farmers in dealing with artificial fertilisers. There are, however, other grounds of choice besides cost. High grade is an advantage where heavy dressings are required, for handling costs are reduced. For light dressings carbonates are often favoured because they are less unpleasant to handle than burnt limes. Injury to germination of seeds is also possible if heavy dressings of quicklime are put on shortly before sowing, and in such cases again the carbonates are favoured. On the other hand, for accelerating the decomposition of old turf and sweetening overstocked pastures the more active oxide is preferred. Carbonate has a decided advantage if the material has to be stored in bags.

There are in commercial limes and carbonates secondary constituents of agricultural importance whose amounts vary considerably according to the origin of the parent material. The most important of these are (1) Magnesium compounds derived from dolomitic limestones, and (2) Silicates and compounds of iron and aluminium arising in the burning process from the union of lime and earthy impurities contained in the raw limestone. The former class forms the magnesian limes and the latter the " lean " or hydraulic limes.

In farming circles the limes and carbonates that are high in calcium and poor in these secondary constituents are handled with most confidence, largely because the " fat " limes slake readily and are high in CaO, and because of the crop injury that takes place from time to time due to the use of heavy dressings of magnesian lime. Consequently the methods of analysis prescribed under the Fertiliser and Feeding Stuffs Regulations are designed to measure calcium oxide, hydroxide, and carbonate, but to ignore all other calcium and magnesian compounds. If these compounds were completely without value in the soil this would be satisfactory, but in certain circumstances this is far from being the case. This position will be further developed in a later and more technical article.

The Thermochemical Basis of Cement Manufacture.

By H. ELSNER v. GRONOW.

THE work described has been mostly carried out by the author in conjunction with E. Schwiete, and is translated from *Zement* (1936, p. 437). Some of it has not been published before and the rest is to be found in publications not easily obtained, so that the collection of it into one paper may be of use to those engaged in the production of cement. The investigations have been concerned mainly with :

(1) The measurement of the specific heats of cement raw materials, clinker minerals, and Portland cement clinker from 20 deg. C. to high temperatures and the calculation of the specific heats of cements from the specific heats of the clinker minerals.
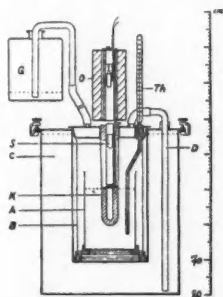

Fig. 1.—Calorimeter for Determining Specific Heat.

(2) The experimental determination of the most important heat changes which occur in the burning of cement : (*a*) The determination of the endothermic effect in the decarbonation of limestone ($CaCO_3$) at 907 deg. C. (*b*) The endothermic effect of the expulsion of water from kaolinite or clay in the raw material ; this is obtained as the difference of the heats of solution of kaolin and metakaolin, at room temperature or slightly higher, in hydrofluoric acid and converted to the value at 450 deg. C. by means of the specific heats of the components [for the estimation of which see under (1)]. (*c*) The determination of the exothermic effect in the formation of Portland cement clinker from clay and limestone and from blastfurnace slag and limestone. The calculation of the exothermic effect from the gross chemical analysis of the finished clinker and its mineral composition. (*d*) The amounts of heat required at high temperatures for the formation of the flux or liquid portion of the clinker.

(3) The preparation of the complete heat balance of the plant for burning cement based on the heat changes described under (1) and (2).

(1) Measurement of the Mean Specific Heat up to 1,500 deg. C.

The copper-block water calorimeter shown in *Fig.* 1 is used for this purpose. The vessel *A*, which contains the liquid for the calorimeter, is protected from loss of heat by means of a highly polished jacket *B* inside the thermostat *C*. From 1 to 3 g. of the substance the specific heat of which is required is placed in a small platinum crucible with 0.03 mm. walls and heated up to 1,500 deg. C. in the platinum resistance-furnace *O*. In order to obtain the exact temperature of the specimen a platinum-rhodium thermocouple is used ; the method of fixing this can be seen in *Fig.* 1. The voltage from this thermocouple is continuously recorded by a mirror galvanometer, and is compensated by a Wolff's compensation apparatus against a standard thermocouple.[1] In this way the small deviations of moving coil instruments are avoided. This is necessary, because the accuracy of the experimental determinations should be sufficient to give the mean specific heats to the fourth place of decimals. When the specimen has been suspended in the furnace *O* by the thin platinum wire (*Fig.* 1) for half an hour at constant temperature, the opening of the furnace is brought over the centre of the calorimeter and the thin platinum wire withdrawn so that the specimen falls first into the silver crucible *S* and then both immediately fall into the copper block *K* without loss of heat. The furnace is immediately removed from the vicinity of the calorimeter to avoid radiation from it affecting the liquid in the calorimeter. Water then circulates through the calorimeter cover from the vessel *C* into the glass flask *G* which has been immersed for this purpose under the level of the liquid in the calorimeter. The temperature rise of the calorimeter is measured by three copper-constantin thermocouples. The current from the thermocouples is read on a sensitive mirror galvanometer and converted to temperature by means of the Regnault-Pfaundler formula.[2] The true temperature of the liquid in the calorimeter (3 litres of water) is given by the thermometer *Th* ; this can be replaced by a Beckmann thermometer for obtaining the temperature rise in the calorimeter after removing the specimen. The mean specific heats of a number of substances from 20 deg. C. to various temperatures commencing with 100 deg. C. are given in Tables I and II. The conversion of the value of $\bar{c}$ obtained experimentally to the mean specific heat from 0 deg. C., which is often required, can be obtained as shown by W. P. White[3] from the formula

$$c_1 = \bar{c} - \frac{20 \text{ deg.}}{T} \, (\bar{c} - c)$$

where $\bar{c}$ is the measured mean specific heat from the calorimeter temperature 20 deg. C. to the temperature T to which the substance is heated, c is the mean specific heat from 0 to 20 deg. C., and c_1 is the required mean specific heat from 0 to T deg. C. The value for c cannot be obtained accurately enough by the calorimeter method, because the temperature rise in the calorimeter is very small for small differences of temperature of the specimen and this leads to large errors.

[1] O. Wolff, *Zeitschr. für Instrumentenk*, Vol. 23, 1903.
[2] Müller-Pouillet, *Lehrbuch der Physik*, Vol. 3, 174, 1907.
[3] W. P. White, *Am. Journ. Science*, Vol. 28, 339, 1909.

The dilatometer-calorimeter method described by the author,[4] which gives the true specific heat, can be used for this purpose as it is suitable for substances of low thermal conductivity in the range of temperatures near room temperature. The true specific heat between o deg. and 20 deg. C. does not differ materially from the mean specific heat over this range.

If a dilatometer is filled with pieces of a substance whose specific heat is to be determined and with a liquid, and is then heated with a known quantity of electrical energy by means of a heating coil in the dilatometer, the specific heat of the contents can be calculated from the heat input to the calorimeter and the temperature rise which is given by the expansion in volume of the contents. It is not necessary to know the coefficient of expansion of the liquid or specimen. It is simpler to obtain the total expansion of the system liquid + specimen + dilatometer for rises of 1 deg. C. by immersing the dilatometer-calorimeter in a liquid at various temperatures and noting the position of the meniscus in the capillary at these temperatures. If the specific heats of the liquid and the glass vessel are known the specific heat of the specimen can be calculated.

Fig. 2.—Dilatometer-Calorimeter according to Elsner v. Gronow for determining the true Specific Heat at 20 deg. C.

The dilatometer-calorimeter is shown diagrammatically in *Fig.* 2. A platinum heating spiral is wound on the glass tube S; the ends of the wire are led by means of glass seals through the calorimeter wall. The glass tube S hangs from the glass stirrups a. The specimen is introduced through the tube b, which is open at first. After filling, the tube b is sealed and the dilatometer evacuated. The liquid (e.g., petroleum, or water in the case of substances unaffected by it) is introduced by means of a three-way tap through the calibrated capillary. Very accurate data are available[5] for the specific heat of water.

If the calorimeter is filled with g_1 grams of the specimen and g_2 grams water having coefficients of expansion a_1 and a_2 respectively, and K calories are put into the apparatus causing a volume increase $\triangle v$, if $\triangle v_1$ is the expansion of the dilatometer vessel for 1 deg. C. then the temperature rise of the whole calorimeter is

$$\triangle t = \frac{\triangle v}{g_1 a_1 + g_2 a_2 - \triangle v_1}$$

[4] H. Elsner von Gronow, Die spezifische Wärme, die Temperaturleitfähigkeit und die adiabatischen Temperaturänderungen im Erweichungsintervall der Gläser. Leipzig und Göttingen, 1930, p. 2.

[5] Thiesen, Scheel und Diesselhorst, *Abh. d. phys.-techn. Reichsanstalt*, Vol. 3, 69, 1900.

TABLE 1.

The Specific Heats of Raw Materials and Clinker Minerals.

Deg. C.	SiO_2	CaO	$CaCO_3$	$\alpha\text{-}Al_2O_3$	C_3S	$\beta\text{-}C_2S$	$\gamma\text{-}C_2S$	CA	C_4A_3	C_3A	K	AS_2	H	Pz	Tz	C_2AS
20—100	191	188	209	212	—	—	189	204	—	—	—	201	—	—	201	—
20—200	207	—	—	222	—	—	—	—	—	—	—	215	—	—	—	—
20—300	220	201	234	232	207	—	207	222	217	212	268	225	216	208	219	220
20—400	232	204	244	241	213	—	213	228	—	—	277	234	223	215	226	225
20—450	239	205	248	246	216	—	216	231	—	—	280	238	225	217	229	227
20—500	246	206	251	249	218	223	219	234	228	221		241	226	220	232	229
20—600	256	207	258	254	223	227	223	238	233	—		246	230	225	236	233
20—675	258	209	261	258	226	231	227	241	—	—		249	236	228	239	236
20—700	259	210	262	259	227	233		242	235	226		250	237	229	240	237
20—800	261	211	264	262	231	238		246	238	—		254	241	233	244	240
20—900	263	213	266	265	234	242		250	240	229		258	243	236	248	243
20—1,000	265	214		268	238	245		252	242	—		261	246	239	250	246
20—1,100	266	215		271	241	249		255	244	232		265	250	242	253	249
20—1,200	267	216		274	242	252		256	246	—		267	257	249		252
20—1,300	270	217		276	244	254		258	248	235		268	277	255		256
20—1,400	271	218		279	246	—		259	250	—		270		262		—
20—1,500	272	219		281	248	—		—	—	—		—		270		—

Tz = Aluminous cement.   Pz = Portland cement.   H = Blastfurnace slag.   K = Kaolin $Al_2O_3 . 2 SiO_2 . 2 H_2O$, AS_2 = Metakaolin $Al_2O_3 . 2 SiO_2$.

The heat energy put into the calorimeter is equal to the sum of the changes in the heat content of the specimen, the liquid, and the glass vessel. Let c be the specific heat of the specimen, c_w that of the water, and W the change in heat content of the glass vessel for 1 deg. C., then

$$K = \triangle t.g_1.c + \triangle t.g_2.c_w + \triangle t.W$$

from which is obtained the true specific heat of the specimen, namely,

$$c = \frac{K}{\triangle t.g_1} - \frac{g_2.c_w + W}{g_1}$$

If the coefficients of expansion a_1 and a_2 can be taken as independent of the temperature for a temperature interval of about 3 deg. C. and the same can be assumed for $\triangle v_1$, then the total volume is independent of the distribution of the liquid layers of various temperatures in the calorimeter. If this holds, $\triangle v$ is not affected if the liquid is somewhat warmer in the upper portion of the dilatometer.

In the determination of the specific heat of alumina the author used the material known as " Sinterkorund " which has been marketed for about three years by Siemens-Halske, of Berlin. This is a pure form of a-corundum. The earlier workers must have used a very porous material for their measurements, and on account of its low thermal conductivity it was not possible to obtain a uniform temperature rapidly. The values for Al_2O_3 for 100 and 200 deg. C. in Table I are extrapolated. The values obtained by W. A. Roth for the porous material are 0.206 for 100 deg. C. and 0.216 cal. per g. for 200 deg. C. All the specific heats are given to three decimal places only. In the original papers they were given to four decimal places.[6], [7], [8]

Method of Using Table I.—The figure 239 in Table I means that the mean specific heat of the substance from 20 deg. C. to the corresponding temperature (450 deg. C.) has the value 0.239 cal. per g. A horizontal stroke in the table means that the value at this temperature can be obtained by interpolation between the neighbouring figures. Blank spaces mean that the substance is not stable under normal conditions, e.g., Kaolinite over 450 deg. C. and limestone over 900 deg. C.

The specific heat of aluminous cement has been calculated from the specific heats of dicalcium silicate and monocalcium aluminate assuming a mineral composition of 23 per cent. C_2AS + 77 per cent. CA. The specific heat of metakaolin was determined on Zettlitzer kaolin calcined at over 600 deg. C. Probably the specific heat of dehydrated kaolin, which has not undergone crystallisation of the amorphous alumina at about 900 to 1,000 deg. C. (formation of γ-Al_2O_3) will be different from that given in Table I for temperatures below 900 deg. C.

The values for silica determined by Wietzel[9] revised in part (Table I, col. 2), have been used.

If the specific heats of the calcium silicates are calculated by the Neumann-Kopp Law from the sum of the molecular heats of the components the difficulty

[6] Elsner von Gronow und Schwiete, *Zeitschr. f. anorg. Chem.*, Vol. 216, 1933, 109.
[7] H. E. Schwiete, *Zement*, Vol. 21, 362, 1932.
[8] Schwiete und Elsner v. Gronow, *Zement*, Vol. 24, No. 13, 1935.
[9] R. Wietzel, *Zeitschr. f. anorg. Chem.*, Vol. 116, 76, 1921.

arises that the assumption of a type of silica and its specific heat in the calculation is somewhat arbitrary. For instance, dicalcium silicate has a much larger mean specific heat than the sum of the equivalent amounts of CaO and SiO_2 if the values for silica as quartz are taken from Wietzel's figures.[9] The specific heats of quartz glass, amorphous silica, and a-β-SiO_2 measured by Roth and Bertram[10] are in every case smaller than those of Wietzel. The fact remains, however, that in order to heat 1 molecule β-2 $CaO.SiO_2$ a much larger amount of heat is required than to heat 2 Mols. CaO + 1 Mol. SiO_2 through the same temperature range. For comparison with the figures in Table I the mean specific heats $\bar{c}$ (20 deg. C.) determined by Roth and Bertram are given below :—

	Deg. C.	cal/g.
Quartz-glass	855	0.247
	1,300	0.263
	(commencing to soften)	
SiO_2 (amorphous)	900	0.2388
a-β-SiO_2	900	0.2588

The specific heats of 1 Mol. tricalcium silicate are only slightly different from the sum of the specific heats of 1 Mol. β-dicalcium silicate and 1 Mol. free lime. This agrees with other determinations and is due to the weak bond of the third molecule of CaO in tricalcium silicate.

The specific heats of pentacalcium trialuminate were calculated from the specific heats of tricalcium aluminate and free lime. Up to 600 deg. C. the mean specific heat of C_3A can be obtained from the sum of the molecular heats of CaO and Al_2O_3. The specific heat of aluminous cement was obtained for a mixture containing 77 per cent. monocalcium aluminate. The actual distribution of the rest (23 per cent.) as pentacalcium trialuminate, gehlenite, or β-dicalcium silicate does not materially affect the result.

TABLE II.

ANALYSES OF PORTLAND CEMENT CLINKER (Pz) AND BLASTFURNACE SLAG (H).

	Clinker (Pz)	Slag (H)
	Per cent.	Per cent.
Loss on ignition	0.42	—
Silica	22.58	34.48
Alumina	5.88 }	14.47
Ferric oxide	3.02 }	(0.9 FeO)
Lime	64.95	44.12
Magnesia	2.24	2.30
Sulphur as SO_3	0.62	1.29
Alkalis	0.43	—
Manganous oxide	n.d.	2.29

The specific heats of gehlenite (C_2AS) and air granulated basic blastfurnace slag (H) were measured up to 1,300 deg. C. Gehlenite is an important constituent of German slags used in the manufacture of Portland cement from blastfurnace

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[10] Roth und Bertram, quoted from Landolt-Börnsteins Tabellen.

slag and limestone. The mean specific heats given in Table I probably include a portion of the latent heat of fusion and are greater due to the very large increase of the true specific heat of the glass at these temperatures.[4] Hence they exceed those of gehlenite at high temperatures but agree at lower temperatures. In Table II are given the analyses of slag (H) and the Portland cement used in the tests by H. E. Schwiete.[7]

In order to obtain the specific heats of Portland cement and aluminous cement the sum of the specific heats of the mineral components may be used and the calculation of the components may be made by Bogue's method. The mineral composition of the Portland cement for which the specific heats are given in Table I is 9.2 per cent. C_4AF ; 10.5 per cent. C_3A ; 41 per cent. C_3S ; 34 per cent. C_2S ; 1.95 per cent. free lime ; 2.24 per cent. MgO ; 0.62 per cent. S determined as SO_3 and present as $CaSO_4$. MgO occurs for the most part in solid solution in the brownmillerite[11] or, in the case of extremely rapid cooling from sintering temperature, as a constituent of an interstitial glass of the following composition (according to Lea and Parker) : 34.5 per cent. C_4AF ; 33 per cent. C_3A ; 5 per cent. C_5A_3 ; 18 per cent. C_2S ; 1.6 per cent. alkalis ; and 8 per cent. MgO.[12]

It is very necessary to know the specific heat of the brownmillerite—MgO solid solution or the interstitial glass for calculating the specific heat of Portland cement clinker from its mineral composition. Since this has not yet been measured a value must be assumed. The final result for the clinker will not be seriously affected by this since the amount of material of unknown specific heat is at most only 10 to 25 per cent.

A comparison of the specific heats of Portland cement given in Table I shows that they do not differ very much from those of tricalcium silicate up to a temperature of 1,100 deg. C.

The specific heats of raw materials as determined by Schwiete and von Gronow[6] have already been given in CEMENT AND CEMENT MANUFACTURE (August, 1935), and will therefore not be repeated.

To heat 1 g. of raw material containing 60 per cent. limestone and 40 per cent. blastfurnace slag (the composition of which is given in Table II) from 20 deg. C. to 1,300 deg. C. requires 292 cal. If the raw material consists instead of clay and limestone and is heated through the same range of temperature the heat required is 313 cal. The chemical composition of this raw material is 14.0 per cent. SiO_2 ; 4.55 per cent. Al_2O_3 ; 1.35 per cent. Fe_2O_3 ; 42.3 per cent. CaO ; total sulphur as SO_3 1.4 per cent. ; 4.0 per cent. H_2O ; 32.0 per cent. CO_2.

Instead of using the method of calculation for determining the heat balance in cement burning given at the end of this paper, the following specific heats of the raw material may be used :

$$\frac{292}{1280} = 0.2283 \text{ cal. per g. per 1 deg. C. and } \frac{313}{1280} = 0.2443 \text{ cal. per g. per 1 deg. C.}$$

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[11] Schwiete und zur Strassen, *Zement*, Vol. 23, No. 36, 1934.
[12] Lea and Parker, *Build. Res. Techn. Paper*, No. 16, 1935.

(2a) Heat required for the Burning of Limestone

The heat required for the decomposition of limestone is the largest item in the thermochemical reactions, and amounts to 395 to 397 cal. per g. The figure for this of 425 cal. per g. which is obtained from the difference in the heats of solution of calcium oxide and calcium carbonate in a suitable acid at 20 to 50 deg. C. should not be taken. If the specific heats of CaO, CO_2, and $CaCO_3$ between 20 and 900 deg. C. are taken as 0.2129, 0.258, and 0.2657 respectively, using Hess's method, the value of 396 cal. per g. is obtained for the heat of dissociation of limestone. The heating of 1 kg. $CaCO_3$ from 20 to 900 deg. C. requires 234 kg. cal. ; the cooling from 900 to 20 deg. C. of 560 g. CaO liberates 105 kg. cal., and of 440 g. CO_2 100 kg. cal. The heat of decomposition at 900 deg. C. is therefore $234 - (105 + 100) = 29$ kg. cal. less than at 20 deg. C., and its value is 396 instead of 425 kg. cal. per kg. This value will be used in the calculation of heat balances. F. M. Lea has arrived by a similar reasoning at the value of 369 cal. per g. = 665 B.T.U. per lb. at 900 deg. C.[13]

(2b) The Endothermic Effect in the Dehydration of Kaolin.

The endothermic effect in the dehydration of kaolin from 450 to 600 deg. C. and the exothermic effect in the conversion of metakaolin at about 950 deg. C. (chiefly crystallisation of the amorphous alumina in the metakaolin) have been determined on a Zettlitzer kaolin (98.5 per cent. clay material $Al_2O_3.SiO_2.2H_2O$ having 13.5 per cent. loss on ignition) at the Kaiser-Wilhelm-Institut für Silikatforschung in the following way. The specimen is dehydrated for six hours in a stream of air dried by phosphorus pentoxide at a constant temperature, and the heat of solution of the product in 40 per cent. hydrofluoric acid is determined. The difference in the heats of solution between kaolin dried at 107 deg. C. and that dehydrated at 600 deg. C. referred to 1 gram of kaolinite is 145 to 135 cal. $(180.5 - 143.0 = 37.5$ kg. cal. per Mol.). The endothermic effect of the formation of metakaolin from the pure oxides is obtained from the difference of the heats of solution of the product heated at 600 deg. C. and 1,050 deg. C. and is 72 ± 10 cal. per g. metakaolin $(164.6 - 180.5 = - 15.9$ kg. cal. per Mol.).

So far it has not been possible to say in what form the silica of the decomposed kaolin occurs. It is likely that it has a higher energy content than quartz. As a direct estimation is not avilable this type of silica has been assumed to be amorphous and its heat content has been taken as 56 cal. per g. greater than that of quartz. This will be referred to again when the exothermic effect in clinker is discussed.

In previous work the heat of dehydration of kaolin at about 500 deg. C. has been usually taken as 135 to 145 cal. per g. as determined by Klever and Kordes.[14] By Hess's Law it can be shown that dehydration at 450 deg. C. requires 78 cal. per g. more than the difference between the heats of solution of equivalent amounts of hydrated and dehydrated material at 20 deg. C. In applying this law the calculations will be referred to 1 gram kaolinite, i.e., $\frac{222}{258}$ g. metakaolin. The

[13] Lea and Desch, The Chemistry of Cement and Concrete, London, 1935.
[14] Klever und Kordes, Veröff. des K.W.I. für Silikatforschung, Vol. 3, 17, 1930.

specific heats of kaolin and metakaolin and the heat from cooling and condensation of 0.1394 g. of water of constitution in the kaolinite from 450 deg. C. to 20 deg. C. (109.6 cal.) have been taken into account. The equation according to Hess's Law will, therefore, be

$$\triangle E \,(450 \text{ deg.}) = \triangle E \,(20 \text{ deg.}) + \frac{222}{258} . \bar{c} \,(450 \text{ deg.}) \, AS_2 - \bar{c} \,(450 \text{ deg.}) \; AS_2.2H_2O$$

$$+ \; 109.6 \text{ cal.}$$

$$= 145 \qquad\qquad + 88.2 \qquad\qquad\qquad - 120.4 \quad + 109.6$$

$$= 223 \text{ cal. per g.}$$

where $\triangle E$ (450 deg.) is the heat content at 450 deg. C. ; $\triangle E$ (20 deg.) is the heat content at 20 deg. C. ; the letters AS_2 and $AS_2.2H_2O$ mean that the preceding figures refer to metakaolin and kaolinite respectively ; $\bar{c}$ is the mean specific heat of the corresponding substance. The values for $\bar{c}$ (450 deg.) for kaolin and metakaolin are from Table I. The molecular weights of the two substances are 258 and 222 respectively.

The value 223 cal. per g. will be used for the heat of dehydration of kaolinite in calculations for the burning of Portland cement. K. Endell[15] has suggested that the alumina in clay may not be present in kaolinite, but in montmorillonite which has a different heat of dehydration and gives a more uniform liberation of heat over a greater range of temperature.

The dehydration of clay in raw meal requires much more heat than has so far been assumed, and is a point in favour of heating the raw meal or clay-bearing slurry by means of flue gas before it enters the kiln. This causes only a slight decarbonation of the limestone at temperatures a little over 900 deg. C., but a considerable dehydration of the clay.

R. D. Pike[16] determined the endothermic effect in the dehydration of an ordinary raw meal containing 396 g. air-dried clay substance per kilogramme of clinker instead of using pure kaolinite. Since the clay substance contains less than 20 per cent. Al_2O_3 it is certain that it contained less than 50 per cent. kaolinite. Using the values of mean specific heat determined by Navias[17] he obtained a value of 208 cal. per g. for the heat of dehydration, which agrees sufficiently well with the author's figure. However, by Pike's method the heat of dehydration of kaolinite is 315 cal. per g., which is certainly too large.

(2c) The Exothermic Effect in the Formation of Portland Cement.

Fifteen years ago R.R. Coghlan[18] gave the exothermic effect in the formation of Portland cement as 108 cal. per g. This figure was based on the calorimetric heats of formation of calcium silicates and aluminates determined by Tschernobajeff. This value still holds even though the method of determination can lead to large errors. In an earlier publication[19] the authors collected the results of numerous workers who obtained the same value of 100 to 120 cal. per g. for the exothermic effect in the formation of clinker from clay and limestone.

[15] Endell, Hofmann und Maegdefrau, *Zement*, Vol. 24, 625, 1935.
[16] R. D. Pike, *Ind. Eng. Chem.*, Vol. 20, 1155, 1928.
[17] Navias, *Journ. Am. Ceram. Soc.*, Vol. 6, 1268, 1923.
[18] R. R. Coghlan, *Concrete (Mill Section)*, Vol. 16, 39, 1920.
[19] Schwiete und Elsner v. Gronow, *Zement*, Vol. 21, No. 35, 1932.

In the following an explanation of the exothermic effect is given, the apparatus used for the determination of the heats of solution is described, and the three methods used by the author in the determination of the exothermic effect in the formation of Portland cement from blastfurnace slag and limestone are given.

If the exothermic effect at 20 deg. C. is 65 cal. when determined from the difference of the heats of solution of the mixture 75.7 per cent. blastfurnace slag and 24.3 per cent. limestone decarbonated at 910 deg. C., it will be found that this value is not different from the value referred to 900 deg. C. because the heat required for heating the original material [blastfurnace slag $(\bar{c} = 0.2434)$ and limestone $(\bar{c} = 0.2129)$] is equal to the liberation of heat in cooling the clinker $(\bar{c} = 0.2357)$ from 900 deg. C. to 20 deg. C. within experimental error :

$$880 \, (0.757 \times 0.2434 + 0.243 \times 0.2129) \approx 880 \times 0.2357$$

A similar relation holds for 1,300 deg. C.

The exothermic effect in the formation of clinker from clay and limestone is, in a similar way, equal to the difference between the heats of solution of the raw meal decarbonated at over 1,000 deg. C. and clinker at 20 deg. C. At 1,300 deg. C. the heat required for 1 g. of raw meal is 292.2 cal. The heat recovery on cooling 0.668 g. clinker is 217.6 cal., and on cooling 0.332 g. CO_2 75.4 $\pm$ 0.9 cal. Hence the heat of formation at 20 deg. C. is not very different from that at 900 deg. C.

These two determinations are very useful because in general the heat of formation in a reaction at a high temperature is not the same as that at 20 deg. C. As will be shown later, the heats of formation of the most important clinker minerals at 1,300 deg. C. are either larger or smaller than those at 20 deg. C. With rising temperature the heat of formation of tricalcium aluminate increases somewhat and that of calcium silicate decreases considerably. Hence we have the circumstance that the exothermic effect obtained from the difference of the heats of solution at 20 deg. C. is greater than that at about 1,300 deg. C.

In the calculation of the exothermic effect in the formation of Portland cement clinker from clay and limestone the heat of solution of the clinker at 20 deg. C. is often subtracted from that of the decarbonated raw meal at 900 deg. C. instead of at 1,050 deg. C. The greater speed of crystallisation of the amorphous alumina at 960 deg. C., and probably also the amorphous silica from the kaolinite, entails an exothermic effect of 72 $\pm$ 10 cal. per g. metakaolin which corresponds to about 16 cal. per g. clinker.

(To be continued.)

Design and Operation of Modern Lime Works.—IV*

By N. V. S. KNIBBS, D.Sc.

The Internal Shape of Shaft Kilns.

LIME kilns have been made in many shapes, some of which have served a local and temporary purpose and are now discontinued, whilst others are still in use. In gas-fired and furnace-fired kilns the shape at the gas-inlet zone is influenced by the limited distance that the gas will travel across the shaft, and this will be considered later in discussing these kilns. Similarly, the shape of the upper parts of some mixed-feed kilns is influenced by the firing arrangements. The discussion here is limited to the influence of the shape of the shaft on the flow of stone and lime and of gases through ordinary mixed-feed kilns and through the main sections of gas-fired and other kilns.

Fig. 15 shows in vertical section the main variations in shape. In cross-section they are ordinarily circular, but oval kilns are sometimes built in the larger sizes.
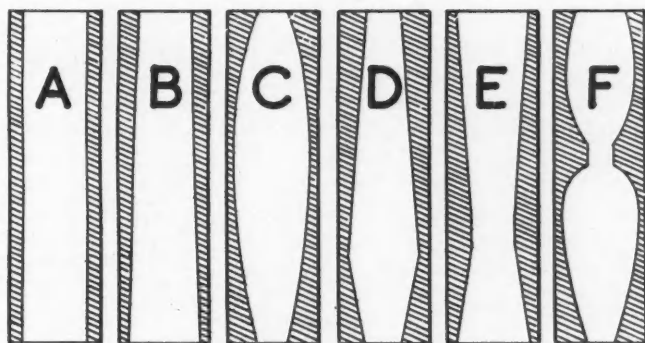

Fig. 15.—Shapes of Shaft Kilns.

The plain cylindrical shaft (A) is the cheapest to build and is a frequent form of modern gas-fired and mixed-feed kilns. It is sometimes modified by widening near the top for a storage zone of larger diameter, but the principle is not thereby altered. Lime shrinks slightly on burning (or considerably if overburnt) so that in a shaft with vertical sides the mass tends to contract slightly from the walls, and therefore to follow down freely, provided the temperature is not such as to cause adherence to the refractory lining.

The outward tapering form (B) facilitates the free passage of the burden downwards. It is employed in blast furnaces, which have considerable taper

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* Previous articles of this series appeared in our issues for January, February and March, 1937.

in this direction (e.g. 1 ft. diameter in 10 ft. of height, and more), but lime kilns, when tapered at all, generally have much less (e.g. 1 in 30). Opinions differ as to the value of outward taper in lime kilns. The taper is inclined to accentuate the fault of excess voids near the kiln walls, and because the lime has to move outwards to fill the shaft it tends to rub on itself in so doing and therefore to be crushed ; a defect that is absent from the parallel-sided kiln, but the tapered kiln undoubtedly is less liable to stick.

Forms (C) and (D) are common in mixed-feed kilns of the older designs. They reduce the area at the charging and discharging points, and thereby simplify the arrangements there, but this is achieved at the cost of less even passage of the lime and gases down and up the shaft respectively. D is sometimes called a " Belgian " kiln, due to its use in the Solvay soda factories there. Form (E) has been used in some gas-fired and furnace-fired kilns with the object of limiting the distance the gas or flame has to penetrate, but it has little to recommend it when the kiln is to burn large stone.

Form (F), with many modifications of the simple shape shown, has been extensively used in the past. It is the form of many mixed-feed kilns of the Aalborg type and of other mixed-feed kilns, and it has been used for furnace and gas kilns. The shape serves the special purpose in the Aalborg type of kiln of allowing an entry for fuel just under the constriction, but it also has the effect in all kilns of concentrating in a narrow neck the blast of hot gases through the lime, which ensures that it will all be well and evenly heated at that point for there is little chance of uneven heating in so narrow a passage. The disadvantages are obvious. The brickwork is somewhat massive at the constriction, and therefore costly, and the concentration of the heat there causes rapid wearing of the lining. Furthermore, the uneven flow above and below the neck tends to counterbalance the advantages of even heating there. Nevertheless, there are many moderately efficient mixed-feed kilns still at work which are of this form.

The effect of the shape on the flow of material through a shaft or similar receptacle has been studied on models of storage bunkers of various shapes. It has also been studied by Block (*Das Kalkbrennen*, 2nd ed., p. 242) on model kiln shapes, using white and coloured marble in layers to enable the flow to be followed. His results agree with what would be anticipated, namely, the retardation of flow down the sides due to inward taper and acceleration due to outward taper. In a kiln of plain cylindrical shape or with very slight outward taper the material was shown to follow down evenly.

Kilns of complicated shape, where the cross-section changes several times, have been proposed with the object of turning the contents over and over to ensure even heating, but the main effect is to crush the lime and therefore to increase the percentage of small lime made. The kiln which makes the least small lime is the cylindrical shaft. A funnel or crucible-shape kiln, like a wide short form of the lower half of (C), is still used abroad for lime burning, and in England a similar type is employed for calcining iron ore, but they are out of date and have only the merit of shortness which allows charging without a hoist.

Size and Proportions of Lime-Kiln Shafts.

SHAFT CAPACITY.—A kiln shaft must have sufficient capacity for the lime and limestone to remain in it for a time sufficient for complete calcination. If the output per hour is A tons and the time required for calcination (including preheating the stone and cooling the lime) is H hours, the volume of the kiln must be sufficient to hold AH tons of lime, or $1.8\,AH$ tons of limestone. The specific gravity of compact limestone is about 2.7, whilst that of soft white chalk is 1.48 or about 0.55 times that of limestone, but the weight per unit volume of the stone in the kiln depends on its grading and packing. The apparent density of limestone of specific gravity 2.7 when finely ground, as gravel, or of other sizes up to kiln stone, varies from about 1.5 to 1.7 when measured in a storage bunker, but in a kiln that is being drawn constantly the figure is less because of the restraining action of the kiln walls which tend to hold up the stone until the packing is much looser than that of stone filled into a bunker. In a kiln of medium diameter the average apparent density is about 1.5 (94 lb. per cu. ft., or 24 cu. ft. per ton) ; if the stone is very evenly graded it is less.

Taking these figures, the volume of a kiln shaft to burn compact limestone must be $1.8 \times A \times H \times 24 = 43AH$ cu. ft. For white chalk of average quality the corresponding figure is $43AH \div 0.55 = 78AH$. If the kiln has a capacity of 24 tons a day $A = 1$ and the volume has to be $43H$. This assumes that the flow of material through the kiln is absolutely even, but with the most careful design such equality is never achieved and therefore the capacity must be increased to allow for unevenness of flow. The curves in *Figs.* 2 and 3* give the times of burning for different conditions. Suppose the average temperature of the burning zone is 1,100 deg. C. (maximum temperature about 1,300 deg. C.) and that the size of the kiln stone is 6 in., then according to Block the volume of the whole kiln should be $29.5 \times 43 = 1,270$ cu. ft. for 1 ton an hour. According to the author's curve (*Fig.* 2) the volume of the burning zone (not the whole kiln) would be $11.5 \times 43 = 495$ cu. ft., or, say, 500 cu. ft. To find the volume of the whole kiln corresponding to this burning zone volume it is necessary to consider the relation between the capacities of the three zones.

CAPACITY OF THE PREHEATING, BURNING, AND COOLING ZONES.—The simple form of mixed-feed kiln is merely a shaft without any demarcation of the three zones of preheating, burning, and cooling. In some mixed-feed kilns the introduction of the fuel at a point some distance down the shaft fixes approximately the junction of the preheating and burning zones, and in a gas-fired kiln the point at which the gas is introduced fixes approximately the bottom of the burning zone. However, even in a kiln in which there is nothing to define the limits of the different zones it is desirable that their extent should be known so that it may be possible to choose an appropriate lining for each section.

The quantity of heat to be transferred in the different zones varies slightly with different temperatures of calcination, but taking the average burning temperature as 1,100 deg. C. the quantities are :

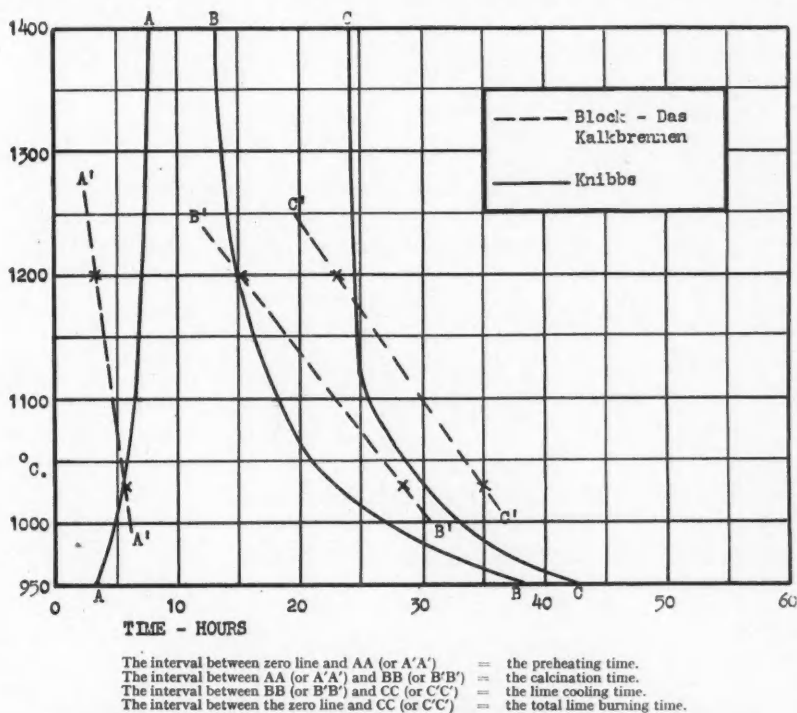* " Cement and Lime Manufacture," February, 1937, pages 50 and 51.

Preheating zone   .. $900 \times 0.27 \times 1.78 = 432$ C.H.U. per lb. of lime.
Burning zone   ..   .. $694 + 200 \times 0.22 = 738$ C.H.U. per lb. of lime.
Lime-cooling zone   .. $1,100 \times 0.21 = 231$ C.H.U. per lb. of lime.

Of the total quantity of heat transferred, therefore, preheating requires 31 per cent., burning 52.5 per cent., and cooling 16.5 per cent. If the rate of heat transference were the same in each zone the total kiln volume would be divisible in this proportion, but actually the rate is very different and it changes greatly with the burning temperature. It has already been shown that the rate of calcination increases rapidly with increase of temperature, and also that the thermal efficiency attainable increases with temperature. Consequently, for a given quantity of lime burnt, there are required a smaller burning zone and larger preheating and cooling zones as the burning temperature is increased. An example will make this clearer.

Suppose a kiln is burning lime in 6-in. pieces with a maximum temperature in the burning zone of 1,200 deg. C. (average about 1,050 deg. C.) and that another is burning the same stone at a maximum temperature of 1,400 deg. C. (average about 1,150 deg. C.)   In the low-temperature kiln the calcination time, according to the author's curves in *Fig.* 2, will be 15 hours, and at the higher temperature 9½ hours, so that the sizes of the burning zones in the two kilns would be approximately in the ratio of 30 : 19 or 1 : 0.63.   The further effect of high temperature is to increase the efficiency of calcination, which entails a decrease of fuel consumption and therefore a decrease of both the air drawn through the cooling zone and the gases passing from the burning to the preheating zone.   For a given output of lime the heat to be transferred in the preheating zones is the same in the two kilns.   In the cooling zones there is more heat to be transferred in the high-temperature kiln if the cooling zone is considered as extending from the zone of maximum temperature downwards, but generally the combustion of fuel and the calcination of stone extend below that point and it is better to consider the cooling zone as extending from a point where the temperature has been reduced to some definite figure, say, 1,000 deg. C., when the heat to be transferred is the same in the two kilns.   In both zones of the two kilns there is, therefore, the same amount of heat to be transferred, whilst in the high-temperature kiln the quantities of air and gas are less and consequently larger capacities are required for the same heat recovery.

To calculate the capacity required in the preheating zone necessitates the use of data which vary with every change of kiln conditions, and the data for the cooling zone must necessarily be arbitrary because the complete recovery of heat there would require an infinitely large cooler (because for complete recovery the cooling air and cooled lime would be at the same temperature).   For a useful calculation it is therefore necessary to assume cooling that is incomplete by some arbitrary amount, e.g. the lime cooled to 50 deg. C.   It is of more value to take figures based on practical experience, even though the paucity of published information limits the number of data, and this has been done in *Fig.* 16.   Block (*Das Kalkbrennen,* 2nd ed., p. 55 *et seq.*) has calculated the preheating, burning

and cooling times for different temperatures and sizes of stone, but apart from the uncertainty of some of the data used, such as the coefficients of heat transfer, and the doubtful validity of some of the assumptions, the calculations are vitiated by the use of incorrect data for quantities that are accurately known, such as specific heats and the dissociation temperature. Nevertheless, as the only published data of the kind known to the author, they are of interest and are shown graphically in *Fig.* 16, together with curves based on the author's own

The interval between zero line and AA (or A'A')   =   the preheating time.
The interval between AA (or A'A') and BB (or B'B')   =   the calcination time.
The interval between BB (or B'B') and CC (or C'C')   =   the lime cooling time.
The interval between the zero line and CC (or C'C')   =   the total lime burning time.

Fig. 16.—Time required for Preheating, Burning and Cooling—6-in. Stone.

measurements. Block calculated the times for only two different temperatures, and in *Fig.* 16 the two sets of points have been arbitrarily joined by straight lines. As already explained, to obtain the capacity in cubic feet of a kiln which will allow these burning times it is necessary to multiply the times shown on the curve by the output of lime in tons per hour and by 43 if the raw material is compact limestone, or by a higher figure if the stone is of lower density (e.g. by 78 for average white chalk). To ascertain the time necessary with stone of another size the curves in *Fig.* 4* may be used, the total time being multiplied

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* " Cement and Lime Manufacture," February, 1937, page 54.

by a factor given by the appropriate curve. For example, if the time for 2-in. stone at a kiln temperature of 1,200 deg. C. is desired, reference to the 1,200-deg. curve in *Fig.* 4 shows that 2-in. stone requires about 1.4 and 6-in. stone about 8.1 hours for calcination. The total time given in *Fig.* 16 for 6-in. stone at 1,200 deg. C. is about 24.5 hours. The total time for 2-in. stone is therefore

$$24 \times \frac{1.4}{8.1} = 4.2 \text{ hours.}$$

To recapitulate : (1) The curves give the minimum time required, and the cubic capacities calculated from them are therefore a minimum. (2) Capacities calculated as indicated assume the even passage of the stone and lime through the kiln, which is never attained in practice, so they must be increased to allow for the unevenness. (3) The curves assume practically continuous drawing and charging, and intermittently-charged kilns must be increased in capacity by the volume of the maximum amount charged at one time. (4) The times given (and therefore the capacities) apply only to kilns of efficient design which ensure evenness of heating, etc. They are, in fact, an indication of the minimum time (and capacity) required in an efficiently designed kiln. (5) The times required for cooling the lime are arbitrary in that they assume cooling to within 30 deg. C. of atmospheric temperature. The long times for cooling when there is a high burning temperature can be reduced with relatively little loss of overall efficiency. (6) The temperatures are average temperatures in the burning zones. The average is often approximately half-way between the maximum temperature and 900 deg. C. but, especially in a mixed-feed kiln, it may be nearer to the maximum than this half-way point. (7) It is assumed that the capacity of the burning zone is not influenced by the time required for combustion of the fuel, but the assumption is justified only if the fuel requires less time to burn than the time required for calcination of the limestone, which is by no means always the case in a mixed-feed kiln. (8) They apply to kilns of a height within the usual range of modern plants.

(To be continued.)

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Gauging Lime Plaster Undercoats with Portland and Gypsum Cements.

THE following note* has been prepared by the Building Research Station for the information of those who desire to use Portland cement or gypsum cement for gauging lime plasters.

Gauging with Portland Cement.

Notwithstanding the advantages of Portland cement as a gauging material certain precautions must be taken to avoid trouble. The chief danger is that a mix gauged with Portland cement is more liable to drying shrinkage cracks than

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one in which gypsum plaster is used. In addition the early strength obtained (say, at 24 hours) is not so great. Against these disadvantages can be set the advantages that most plasterers are thoroughly familiar with the material and are therefore not liable to misuse it, that it assists in protecting embedded steel and iron from corrosion, and that it reduces the tendency to deterioration of lime plastering exposed to damp conditions. Furthermore the setting properties permit working over a much longer period without detriment to the finished work than is the case with mixes gauged with plaster. Mixes gauged with Portland cement may be used safely up to two hours after mixing, so that reasonably large batches of mortar may be gauged at each operation.

An essential precaution is that ample time should be permitted for a first undercoat on lathing to dry out and (as far as is needed to relieve the inevitable drying shrinkage stresses) to crack before proceeding with the subsequent coats. The lime used must be sound, since the addition of a rapid-setting gauging material shows up any unsoundness in a very definite manner. Whereas an ungauged lime mortar may be able to " give " somewhat while unset and soft, in the event of expansion arising due to unsound particles the gauged lime may have hardened and become unyielding before this expansion is completed. Dry hydrated lime to be used in a gauged lime mortar should be purchased under a written guarantee of soundness.

Either lime putty or dry hydrated lime may be used. In the latter case it is preferably soaked (at least overnight) to form a putty, which can then be used in the same way as putty prepared from quicklime. For overhead lathing, especially metal lathing, the addition of an adequate proportion of hair is desirable (2 to 5 lb. per cu. yd. of coarse stuff). With ready-prepared lime coarse-stuff a suitable gauging is 1 part of Portland cement by volume to 10 parts of sanded lime coarse stuff of ordinary composition (nominally 1 : 3). This gives, with a reasonably well-graded clean sand, adequate strength for overhead work on lathing, but a somewhat slower rate of set than a straight cement and sand mortar. For special work, for particularly high early strength, or with unfavourable sands, a gauging as high as 1 : 6 may be required.

With dry hydrated lime unsoaked, suitable proportions corresponding closely to the above are 1 : 3 : 8 or 1 : 3 : 12 (by volume) of Portland cement, dry hydrated lime, and sand. The latter proportion requires a suitably graded sand if it is to be used for overhead work on lathing and in a first undercoat. The leaner mixes can be employed on the solid, on a wall, or as a second undercoat on ceilings. For use on metal lathing the richer mix may be preferable to avoid excessive droppings, and hair should be used in the proportion mentioned.

If a dirty or unduly loamy sand is employed the hardening of the damp mortar may be considerably retarded, as much as three days being required in some cases where a clayey ferruginous sand has been used. Damage may then be done to keys, etc., before the mix has properly set and hardened, even although the ultimate dry strength may be adequate. The remedy is to use a cleaner sand or more cement.

Gauging with Gypsum Cement.

Certain varieties of gypsum cement are frequently used for gauging undercoats. The prolonged set of gypsum cements enables reasonably large batches to be mixed, and the mixed material can be worked for an hour or more without serious loss of strength. The drying shrinkage of lime mortar is not increased by the addition of gypsum cements of this type, and the setting time of the gypsum cement is not affected by being mixed with lime and sand. On the other hand, unless the proportion of gauging material is considerable, the additional strength provided by its use is less than when gypsum plaster or Portland cement is used. Early strength is noticeably lacking even when the gauging is heavy as, although a fast initial set is observed in some brands of this material, this is usually killed during the gauging process. Strength is therefore only obtained by the slow and continuous second set. Gypsum cements of the Keene's cement type, viz. salt accelerated, are not all suitable gauging materials. Their sand-carrying capacity is low and in some cases the admixture of lime is definitely unwise. Gypsum cements recommended by the manufacturers for use with lime are usually suitable materials for gauging undercoats.

Conveying and Elevating in the Cement Industry.

In connection with the illustration of a packing machine incorporating a Redler conveyor-elevator on page 91 of the March number of this journal, Mr. E. D. B. Russell, manager of The Gillingham Portland Cement Co., Ltd., informs us that these packing machines, of which several are in use at Gillingham, are his patent and not the product of Messrs. Redler Patents alone as might be inferred from the article in our last number. Mr. Russell continues : " The machine was designed to get over the difficulty of filling valve bags when the storage was all in open bins of different sizes and different levels. The machine does this successfully, picking up cement from bulk in the bin, being propelled into the heap as required, and loading it into valve bags at the rate of 10 to 15 tons an hour. The chief features of the machine are the mounting of a valve packer on a movable undercarriage and feeding the packer directly by a Redler conveyor-elevator, which by having an open end can pick up the material to be handled direct from bulk. The patent covers the use of any proprietary type of packer, either automatic or hand operated, for this purpose. In practice we are using a small proprietary packer, very much modified for our purpose, from which we can get an output of up to 15 tons an hour."